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RESEARCH MEMORANDUM

for the

Civil Aeronautics Administration

MODEL DITCHING INVESTIGATION OF THE

DOUGLAS DC-4 AND DC-6 AIRPLANES

By Lloyd J. Fisher and Edward L. Hoffman

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Langley Air Force Base, Va.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

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SUMMARY

The ditching characteristics of the Douglas DC-4 and DC-6 airplanes were investigated at Langley tank no. 2. Dynamically similar models of $\frac{1}{16}$ scale were used for the investigation which was conducted in calm and rough water.

The ditching characteristics and the safest ditching procedures were determined by testing at various landing attitudes, speeds, and simulated conditions of damage. The principal methods of obtaining data were by motion-picture and still-picture records and by time-history deceleration records. It was concluded from the model tests that the best ditching with the Douglas DC-4 and DC-6 airplanes could be made by contacting the water at a nose-high attitude with the landing flaps full down. The ditching behavior of both airplanes will be similar. In calm water or small waves the attitude will decrease until the airplane stops in a slightly nose-down attitude that is described as a deep run. Little damage will be sustained at these conditions. In waves of the order of 6 feet high, considerable variation in behavior and damage may occur, depending on how the airplane contacts the waves.

INTRODUCTION

An investigation of the ditching characteristics of the Douglas DC-4 and DC-6 airplanes was conducted at Langley tank no. 2 at the request of the Civil Aeronautics Administration. Various landing attitudes, speeds, and simulated conditions of damage were investigated in

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calm-water and rough-water ditchings with dynamically similar models of the airplanes. The calm-water ditchings were made on the Langley tank no. 2 monorail. The rough-water ditchings, which were restricted to the DC-4 model, were made on the Langley tank no. 2 main carriage and on the outdoor catapult.

Data on the airplanes were obtained from Douglas Aircraft Co., Inc. through the Civil Aeronautics Administration.

APPARATUS AND PROCEDURE

Description of Model

A $\frac{1}{16}$ -scale dynamically similar model of the DC-6 airplane that could be modified to resemble closely the DC-4 airplane was used in the tests. The fuselage and nacelles were equipped with spacer blocks that could be removed to approximate the DC-4 model. The same tail assembly and wing were used in each case. Figure 1 is a three-view drawing of the DC-6 airplane showing the sections that were removable from the model to approximate the DC-4 airplane. Photographs of the model are given as figures 2, 3, and 4. The model was constructed principally of balsa with thin plywood bulkheads in the fuselage and spruce bracings in the wing. Internal ballast was used to obtain scale weights and moments of inertia.

The landing flaps were designed so that they could be made to fail under scale loads. To accomplish this they were held in the deflected position by a fine wire pin. When excessive water loads were encountered on the flaps, the wire pin was sheared and the flaps rotated on their hinges, thus simulating failure.

The landing-gear doors were made removable since it was assumed they would be completely torn away in a ditching. On the basis of the strength data of the fuselage quoted by the manufacturer, it was further assumed that the under surface of the fuselage (except the section between the wing spars) would be damaged. As the extent of the damage would be difficult to estimate, sections of the under surface of the fuselage were made replaceable with scale-strength sections. These sections were expected to sustain damage similar to full-scale damage. The scale-strength sections (see figs. 5 and 6) consisted of a skeleton framework of balsa wood, or cardboard and balsa wood, covered with either thin waterproof paper or 0.001-inch aluminum sheet.

Test Methods and Equipment

The model was attached to a launching carriage at the desired landing attitude with the control surfaces set to hold this attitude in flight. The model was then brought up to flying speed and released so that it would glide onto the water with the preset control surfaces keeping the model at approximately the desired attitude. This method was used for both the indoor and outdoor tests.

The ditching behavior was evaluated from motion-picture and still-picture records and time-history deceleration records. The deceleration records were obtained with a small accelerometer placed inside the model near the pilot's enclosure. The accelerometer had a natural frequency of about 17 cycles per second and was damped to about 65 percent of critical. The reading accuracy was about $\pm \frac{1}{2}g$.

Test Conditions

(All values refer to the full-scale airplane.)

Gross weight.— The DC-4 model was ditched at a gross weight corresponding to 72,000 pounds and the DC-6 model, at a gross weight corresponding to 84,000 pounds.

Location of the center of gravity.— The center of gravity was located at 28 percent of the mean aerodynamic chord and 4 inches above the fuselage reference line.

Landing attitude.— Landing attitude is the angle between the fuselage reference line and the horizontal. Three landing attitudes were investigated: 2°, 7°, and 12°. The 2° attitude is near the three-wheel attitude and the 12° attitude is approximately the three-point, tail-down attitude. The 7° attitude is an arbitrary intermediate selection.

Flaps.— The landing flaps were tested down 50° on the DC-4 model and full up and down 50° on the DC-6 model. At the 50° setting the flaps were attached so that they would fail at scale strength. The scale strength was based on an ultimate flap loading of 270 pounds per square foot.

Landing gear.— The tests simulated ditchings with the landing gear retracted.

Landing speeds.— The landing speeds used are listed in tables I, II, and III. They are speeds at which the model was just airborne and

are approximately the speeds computed from power-off lift curves for the DC-6 airplane. The same lift curves were used for the DC-4 airplane since both models had the same wing.

Conditions of simulated damage.— The models were tested at the following conditions of damage:

- (a) No damage (See figs. 2 and 3.)
- (b) Simulated failure of the landing-gear doors and simulated scale strength of the under surface of the fuselage. (See figs. 5 and 6.) The scale-strength sections were designed to fail under a uniformly distributed load of 8.3 pounds per square inch.

Condition of seaway.— The following conditions of water surface were used:

- (a) Calm water (indoors)
- (b) Irregular waves (outdoors) produced by wind, height approximately $2\frac{1}{2}$ feet, length approximately 50 feet
- (c) Very regular waves (indoors) produced by oscillating plate, height 6 feet, length 180 feet

Both the DC-4 and DC-6 models were tested in calm water, but only the DC-4 model was tested in rough water. The investigation in rough water was limited to landings perpendicular to the wave crests which is generally considered the most severe seaway condition. No rough-water landings were made parallel to wave crests as such landings could be expected to cause damage and decelerations similar to those in calm-water ditchings.

RESULTS AND DISCUSSION

Summaries of the results of the tests are presented in tables I, II, and III. The notations used in the tables are defined as follows:

Ran deeply — A run in which the model stopped abruptly in a slightly nose-down attitude.

Ran smoothly — A run in which the model stopped gradually in a level attitude.

Sequence photographs showing the characteristic behavior of the models are given in figure 7. Time-history curves of longitudinal deceleration are given in figures 8 and 9. Figures 10, 11, and 12 show photographs of the ditching damage sustained by the scale-strength bottoms.

Effect of Landing Flaps

The landing flaps consistently failed when tested at the 50° position and had no apparent detrimental effect. A comparison between the 0° and 50° flap position was made on the DC-6 model at the undamaged condition and 12° attitude. (See table I.) The motions of the model were about the same for both the 0° and 50° flap positions, but the lengths of the landing runs and the maximum longitudinal decelerations were greater at the 0° flap position. Figure 8 presents a comparison of typical time-history deceleration records for the 0° and 50° flap positions.

The 50° flap position should be used in a DC-6 ditching to take advantage of the lower deceleration and slower landing speeds. The 0° flap position was not tested on the DC-4 model, but since the behavior of the DC-4 and DC-6 models was the same with the flaps at 50° it is assumed that the behavior with 0° flaps would also be similar. Therefore, the 50° flap position is recommended for the DC-4 airplane.

Effect of Attitude

The landing attitude did not cause any appreciable variation in the motions of the models but did affect the maximum decelerations and the extent of damage. (See tables I and II.) In the tests with no damage simulated the decelerations at the 2° attitude were higher than at either the 7° or 12° attitudes. The decelerations at the 12° attitude were slightly higher than at the 7° attitude. In the tests with scale-strength bottoms less damage and lower decelerations were obtained at the 12° landing attitude than at the 7° landing attitude on both the DC-4 and DC-6 models. The 2° attitude was not tested with scale-strength bottoms since it was concluded from the tests with no damage simulated that this attitude would not be recommended. The extent of damage to the scale-strength bottoms as affected by landing attitude can be seen from figures 10 and 11.

Since, in the tests with scale-strength bottoms, less damage and lower decelerations were encountered at the 12° attitude, this attitude is preferable for ditching.

Effect of Damage

The effect of damage on the ditching characteristics of the models in calm water is summarized in tables I and II. Figures 10 and 11 are photographs of the damage occurring in these tests.

Figure 11 includes a comparison of the damage sustained by paper- and aluminum-covered scale-strength bottoms on similar runs so that an indirect comparison can be made between photographs of the DC-6 damage and the DC-4 damage. From the photographs, it can be seen that the paper-covered sections have more holes than the aluminum-covered ones. However, the aluminum is stretched and caved in where the extra holes appear in the paper sections. The stretching and caving of the aluminum is probably more typical of the damage on full-scale airplanes.

In general, damage caused shorter landing runs and higher decelerations. (See tables I and II and fig. 8.) The damage also changed the ditching behavior from smooth runs to deep runs. The sequence photographs in figure 7(a) show a typical deep run.

Effect of Seaway

Table III contains a summary of the results of the rough-water tests, and figures 9 and 12 show typical deceleration curves and damage photographs.

The tests in $2\frac{1}{2}$ -foot waves indicated that the waves were not high enough to affect materially the behavior of the airplanes. The motions of the model were the same as those obtained in calm-water tests. (See fig. 7(b) and table III.) The average maximum decelerations and amount of damage sustained by scale-strength bottoms in $2\frac{1}{2}$ -foot waves were even slightly less than those obtained in calm-water tests.

The tests in 6-foot waves indicated that the waves were high enough to be the major factor in the ditching behavior of the airplanes. The behavior and extent of damage depended on how the model contacted the waves. The maximum decelerations obtained were considerably higher than those in calm water and the damage sustained was more severe. From the descriptions of the test runs in table III and the sequence photographs in figure 7(c) it can be seen that the nose, center section, and tail of the models may have received major impacts. If these sections had been made scale strength, the damage may have been greater than that shown in figure 12.

In reasonably calm water or in landings parallel to waves, it is expected that in full-scale ditchings the damage will not be excessive. However, in landings perpendicular to waves, the damage may be excessive if a bad contact is made.

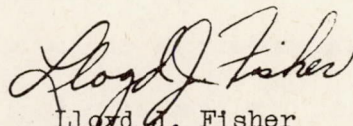
CONCLUSIONS

Conclusions, based on an investigation of $\frac{1}{16}$ -scale dynamically similar models of the Douglas DC-4 and DC-6 airplanes, are as follows:

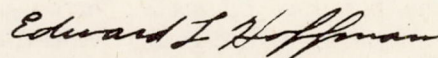
1. The best ditchings with the Douglas DC-4 and DC-6 airplanes will be made by contacting the water at a nose-high attitude with the landing flaps full down.
2. The ditching behavior of both airplanes will be similar. In calm water or small waves the attitude will decrease until the airplane stops in a slightly nose-down attitude that is described as a deep run. Little damage will be sustained at these conditions.

3. In waves of the order of 6 feet high considerable variation in behavior and damage may occur, depending on how the airplane contacts the waves.

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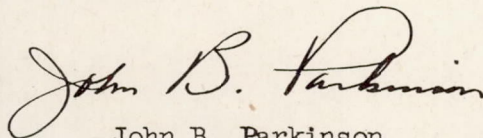


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Approved:



John B. Parkinson
Chief of Hydrodynamics Division

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TABLE I

SUMMARY OF RESULTS OF DITCHING TESTS

IN CALM WATER OF A $\frac{1}{16}$ -SCALE MODEL OF THE DOUGLAS DC-6 AIRPLANE

[All values full scale; gross weight, 84,000 lb]

Landing attitude, deg	2			7			12					
Flap deflection, deg	50			50			0			50		
Landing speed, mph	122			108			126			98		
Behavior Condition of damage	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model
No simulated damage	3	700	Ran smoothly	1	600	Ran smoothly	2	550	Ran smoothly	$1\frac{1}{2}$	450	Ran smoothly
Landing-gear doors removed, scale-strength bottom installed				5	250	Ran deeply				$3\frac{1}{2}$	250	Ran deeply

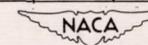


TABLE II

SUMMARY OF RESULTS OF DITCHING TESTS
IN CALM WATER OF A $\frac{1}{16}$ -SCALE MODEL OF THE DOUGLAS DC-4 AIRPLANE

[All values full scale; flap deflection, 50°; gross weight, 72,000 lb]

Landing attitude, deg	2			7			12		
Landing speed, mph	113			100			91		
Behavior Condition of damage	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model	Maximum longitudinal deceleration (g)	Length of run (ft)	Motions of model
No simulated damage	2	650	Ran smoothly	1	600	Ran smoothly	$1\frac{1}{2}$	450	Ran smoothly
Landing-gear doors removed, scale-strength bottom installed				6	200	Ran deeply	$4\frac{1}{2}$	250	Ran deeply

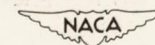


TABLE III
SUMMARY OF RESULTS OF DITCHING TESTS

IN ROUGH WATER OF A $\frac{1}{16}$ -SCALE MODEL OF THE DOUGLAS DC-4 AIRPLANE

[All values full scale; landing attitude, 12° ; landing speed 91 mph; flap deflection, 50° ; gross weight, 72,000 pounds]

Wave height, ft	$2\frac{1}{2}$		6	
Behavior Condition of damage	Maximum longitudinal deceleration (g)	Motions of model	Maximum longitudinal deceleration (g)	Motions of model
Landing-gear doors removed, scale- strength bottom installed	4	Ran deeply	$6\frac{1}{2}$ 6 $7\frac{1}{2}$	1. Tail touched just after wave crest, section under wing hit oncoming wave crest, ran deeply into next wave. 2. Tail touched wave crest, section under wing hit oncoming wave crest, section forward of wing hit next wave crest. 3. Tail hit just before wave crest, dived into oncoming wave.

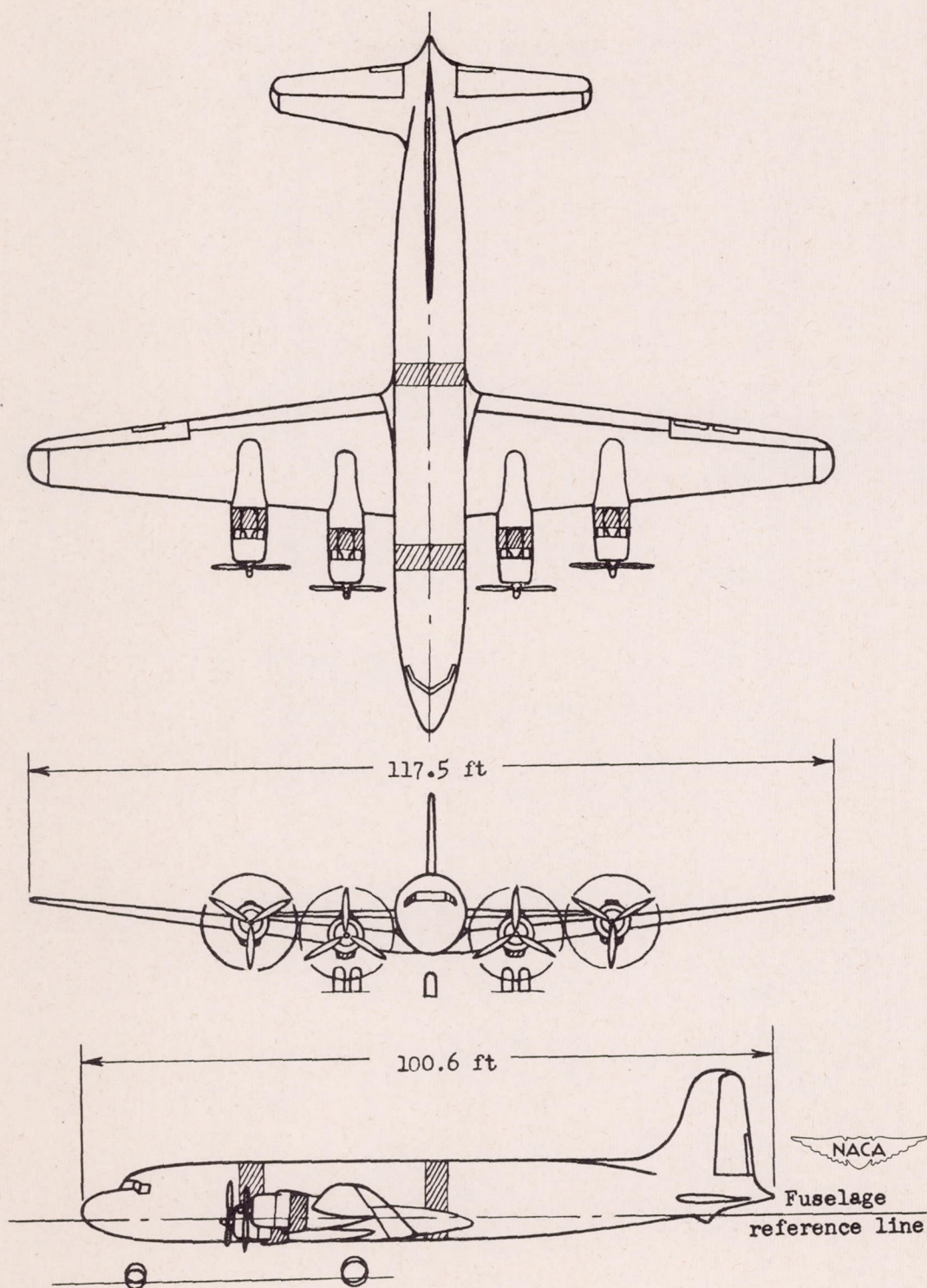
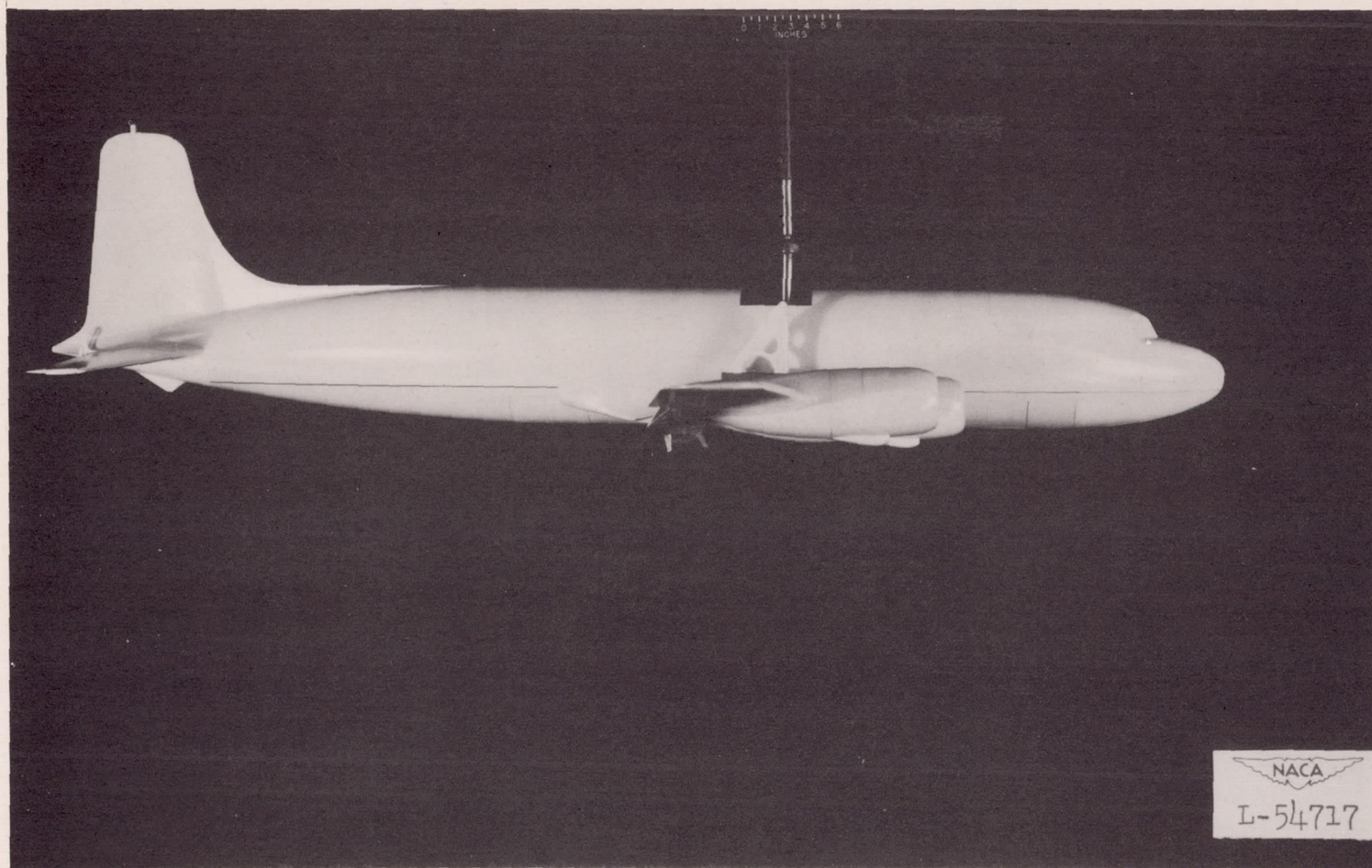
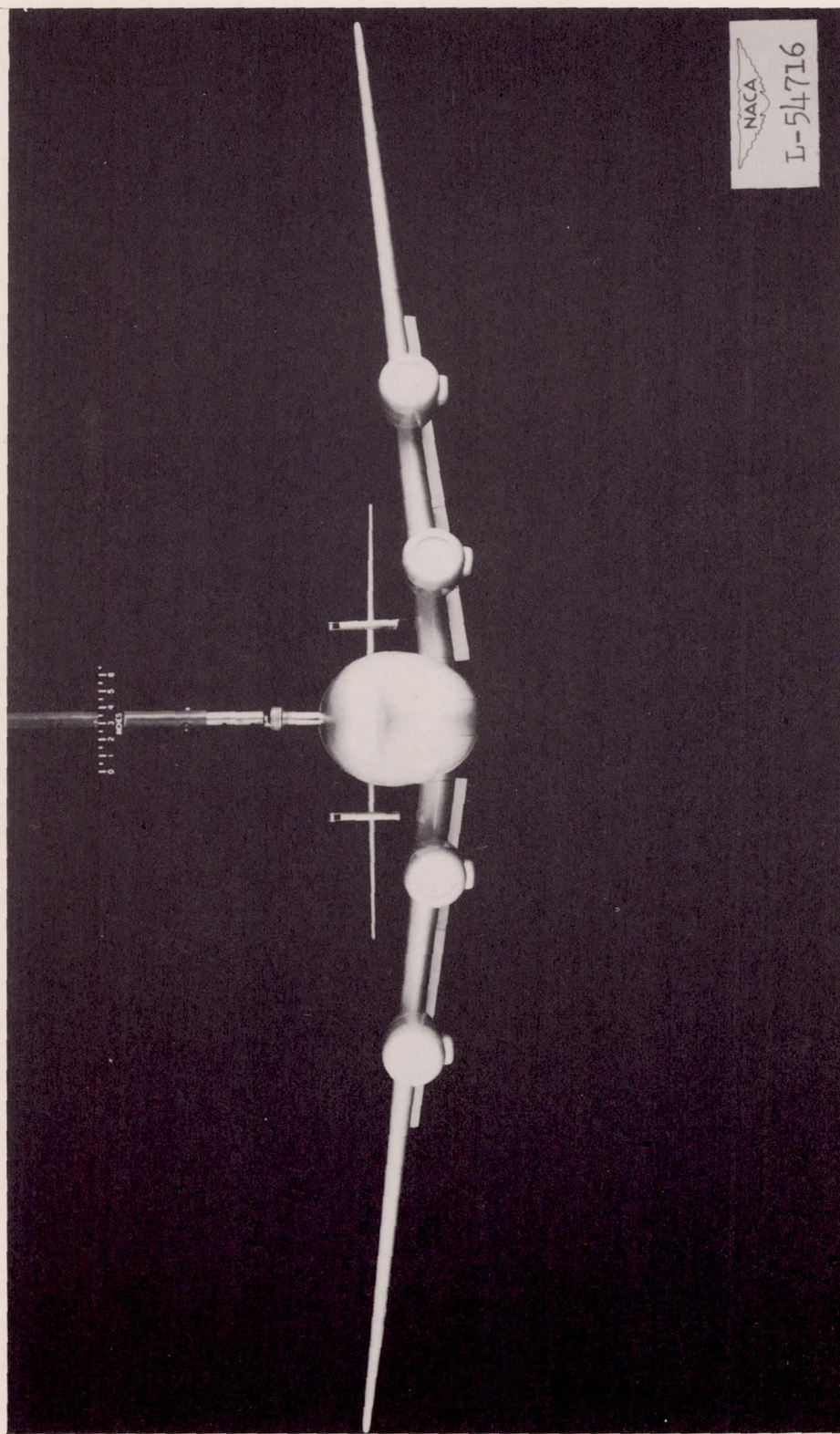


Figure 1.- Three-view drawing of Douglas DC-6 airplane showing sections that were removable (shaded areas) from the model to approximate the Douglas DC-4 airplane.



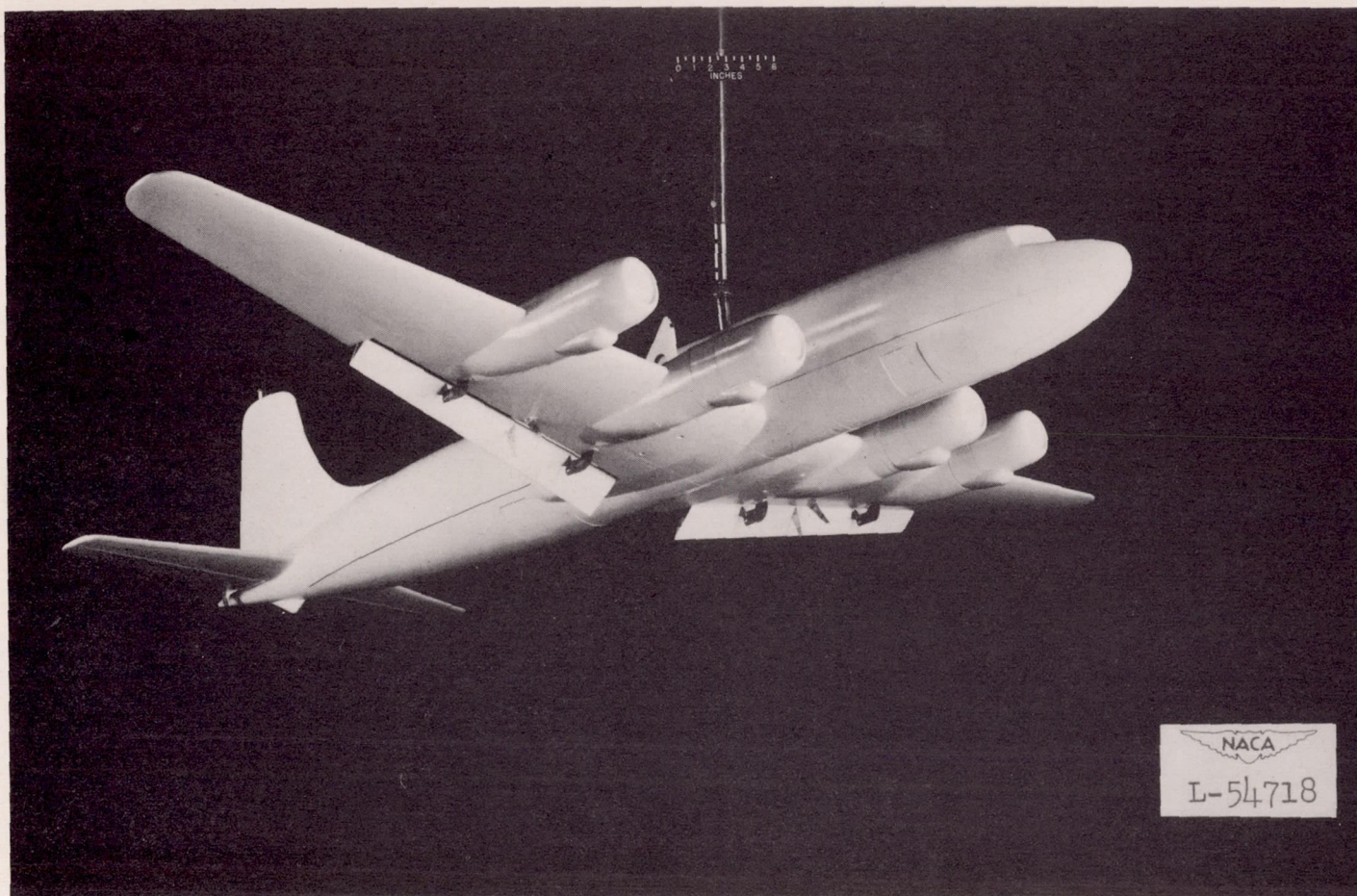
(a) Side view.

Figure 2.- Ditching model of Douglas DC-6 airplane.



(b) Front view.

Figure 2.- Continued.



(c) Three-quarter view.

Figure 2.- Concluded.

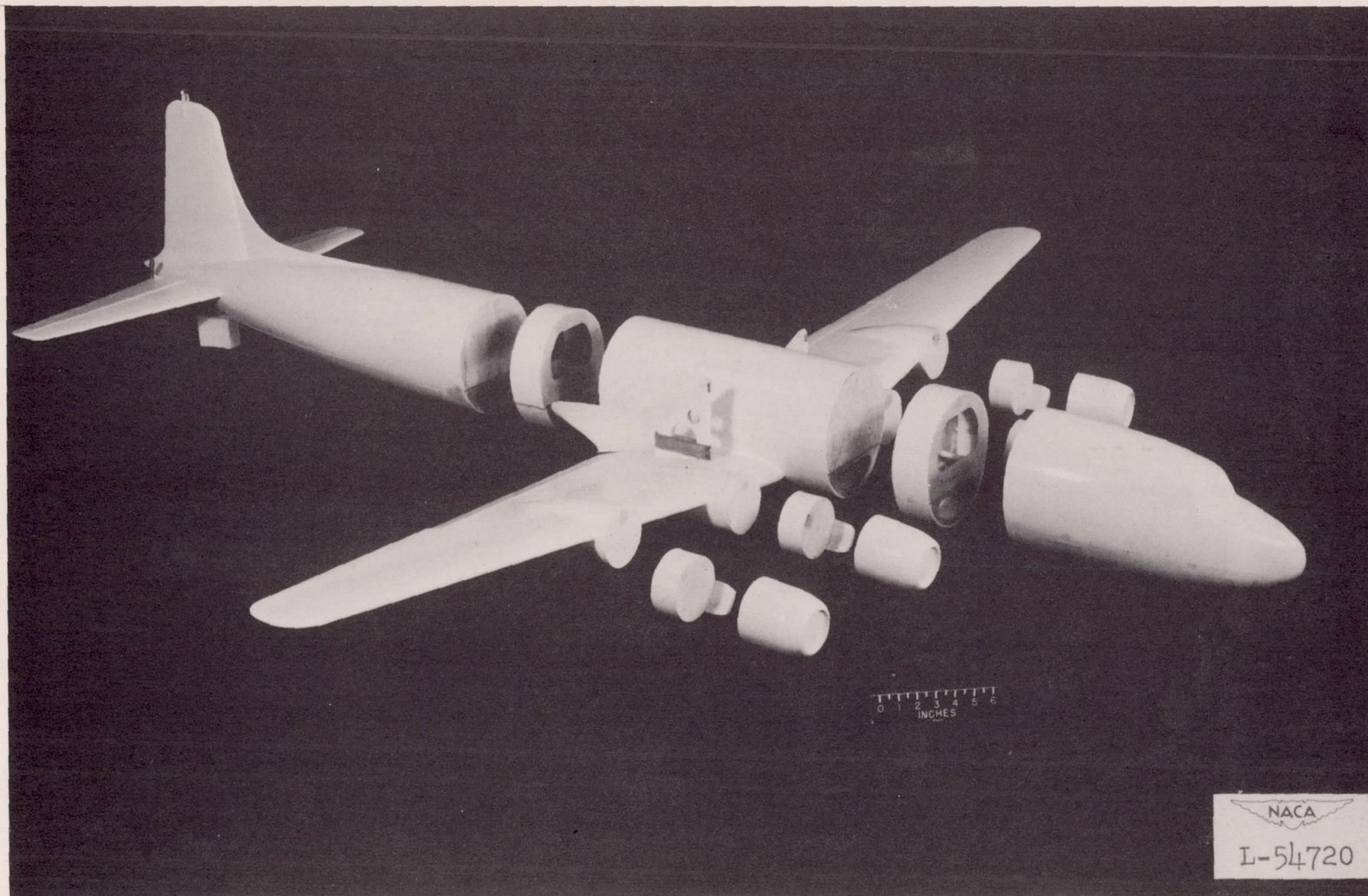


Figure 3.- Exploded view of Douglas DC-6 model showing sections that are removable to approximate Douglas DC-4 airplane.

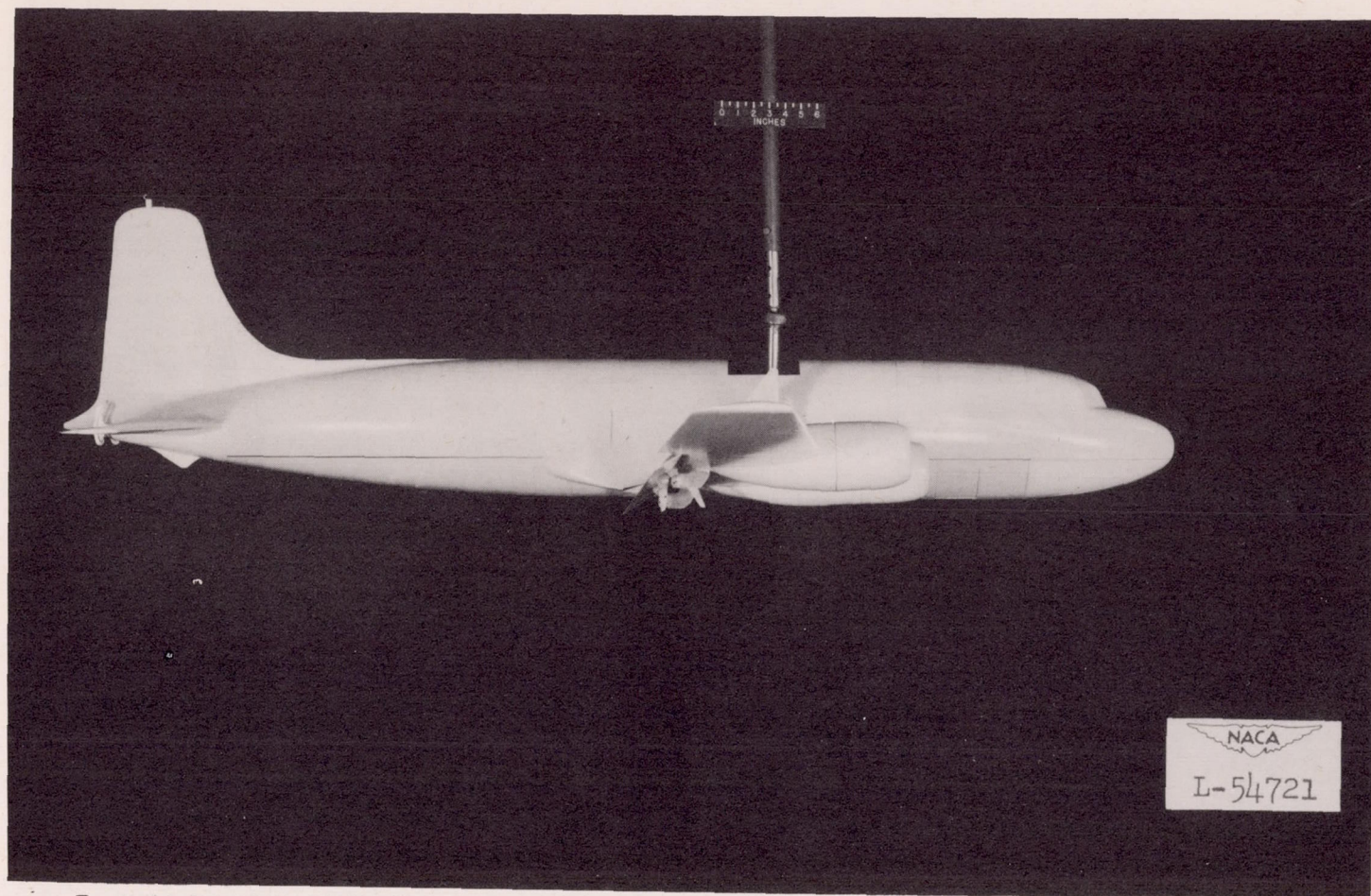


Figure 4.- Side view of ditching model of Douglas DC-4 airplane.

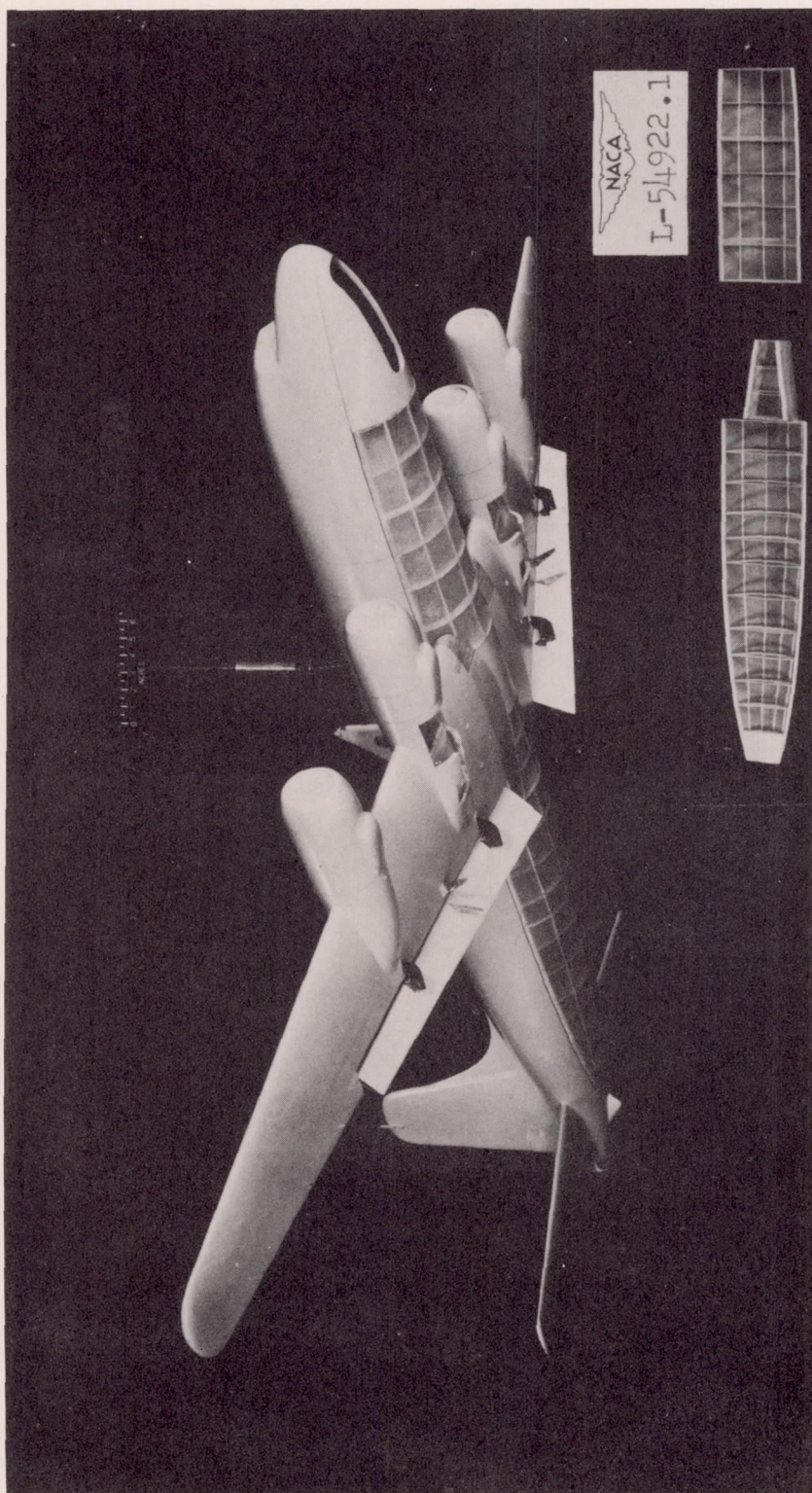
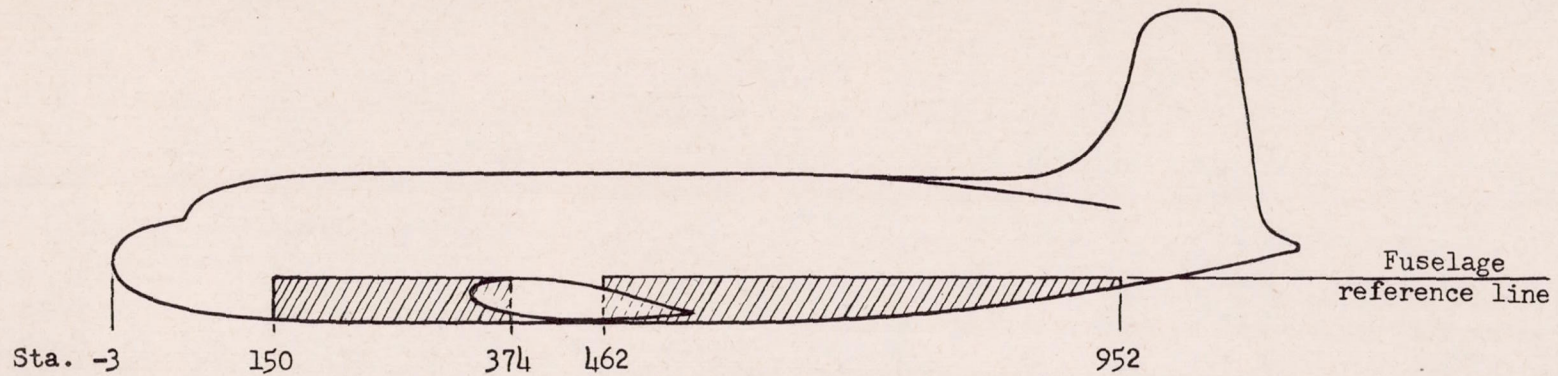
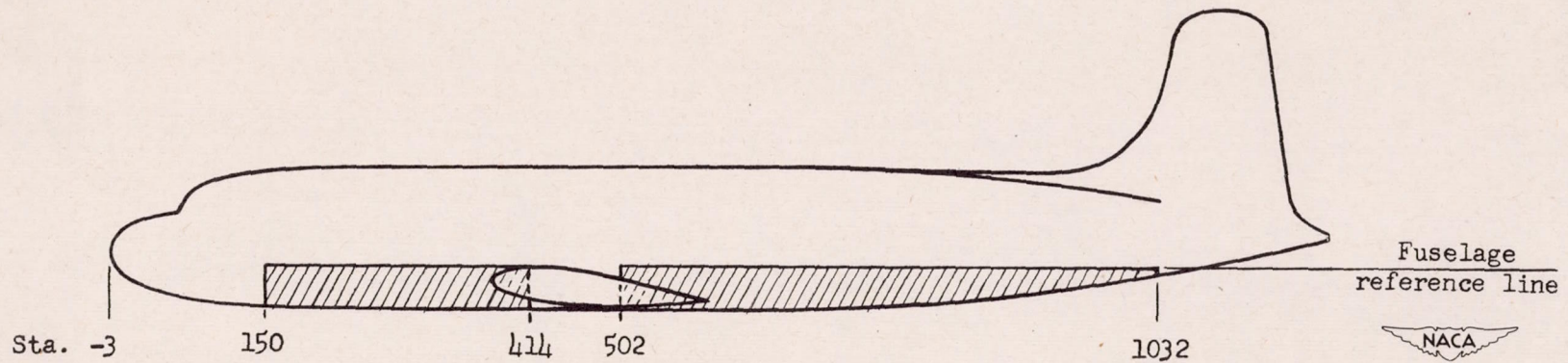


Figure 5.- Douglas DC-6 model with landing-gear doors removed and scale-strength bottom installed.
Inset shows construction of scale-strength bottom.

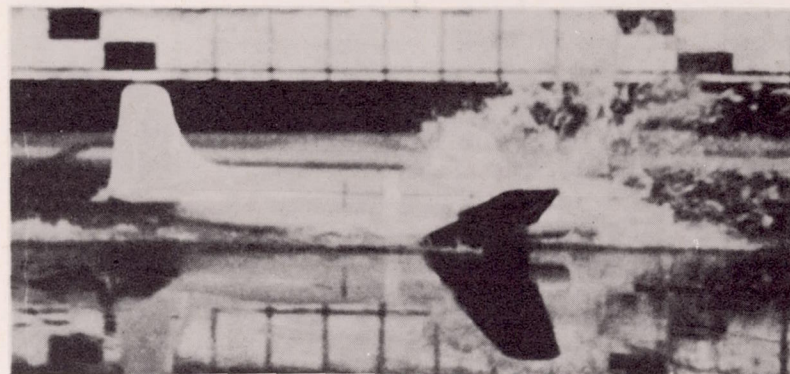
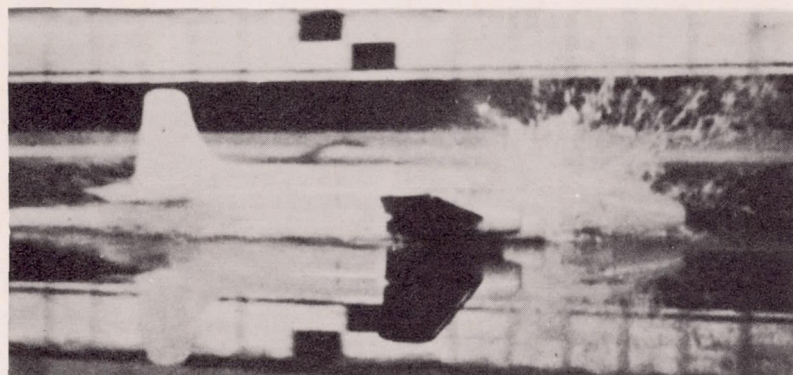
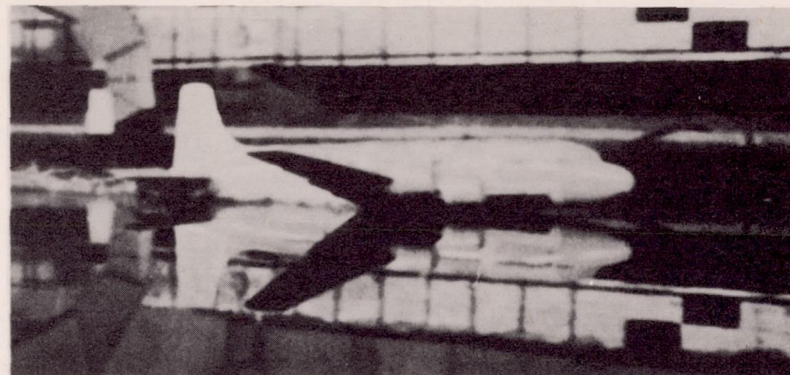
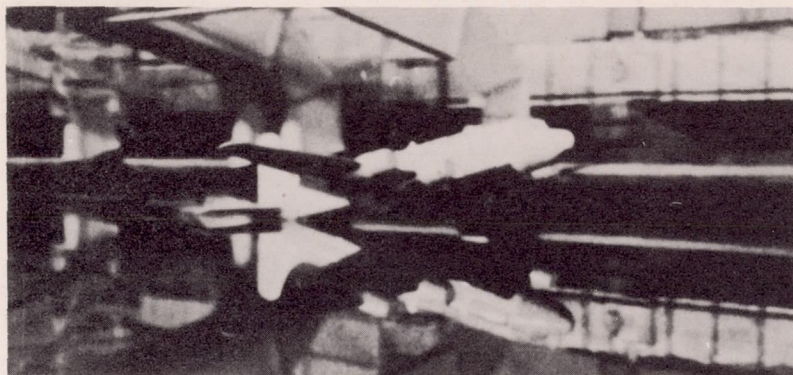


DC-4.



DC-6.

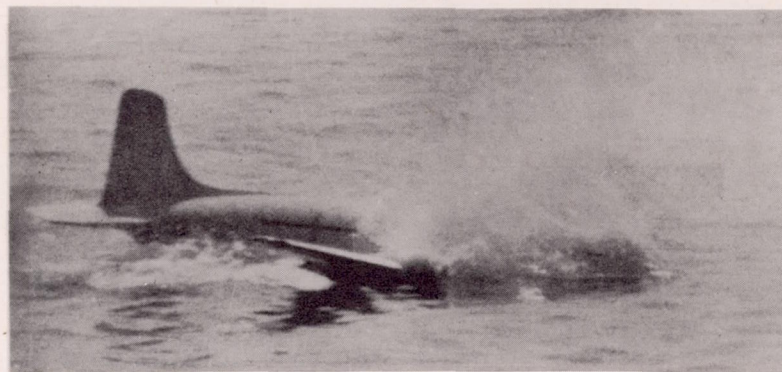
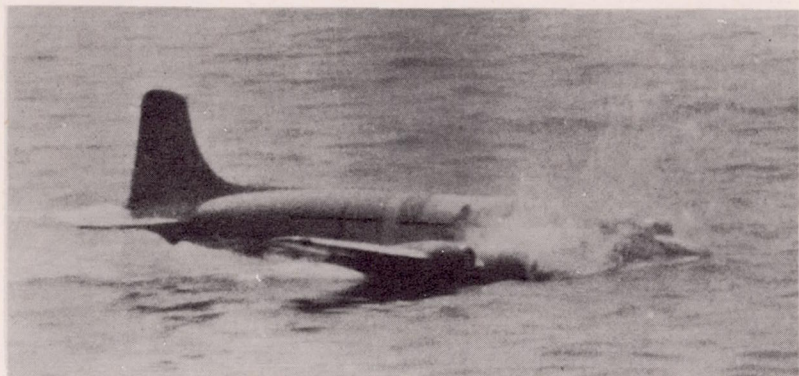
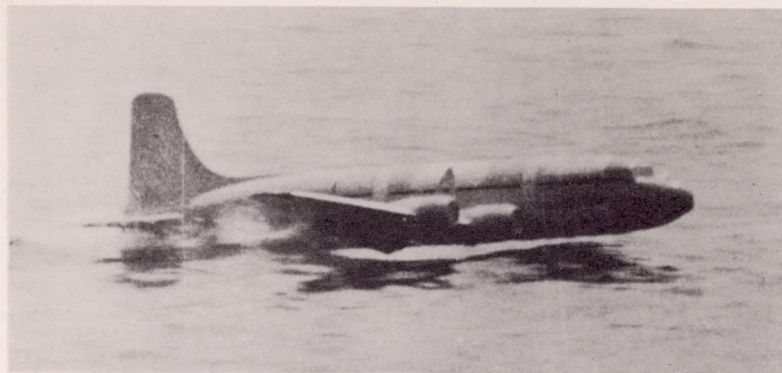
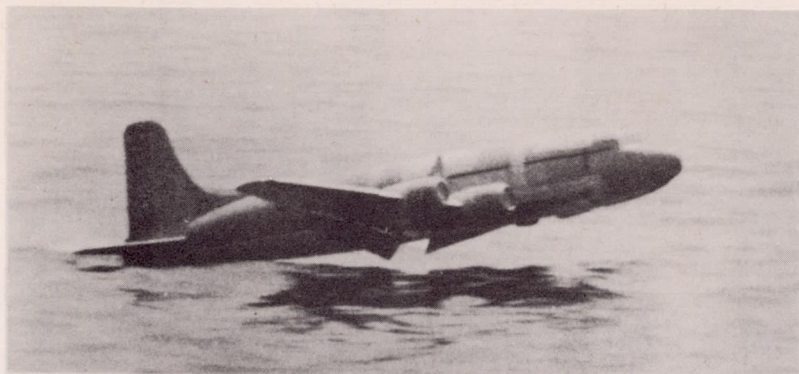
Figure 6.- Location of scale-strength bottoms (shaded areas) on Douglas DC-4 and DC-6 ditching models.



(a) Calm water. Time interval, 0.75 second.

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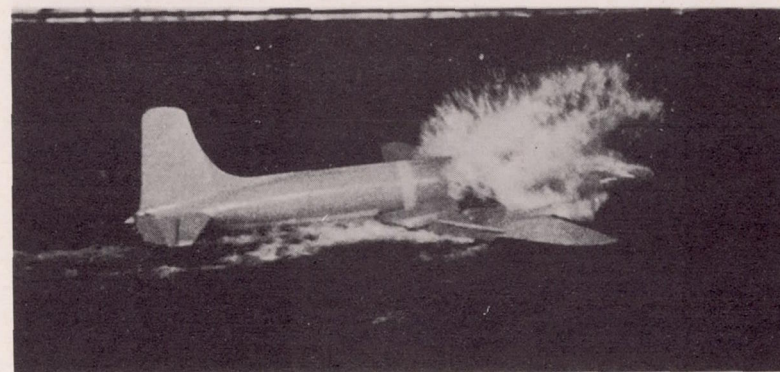
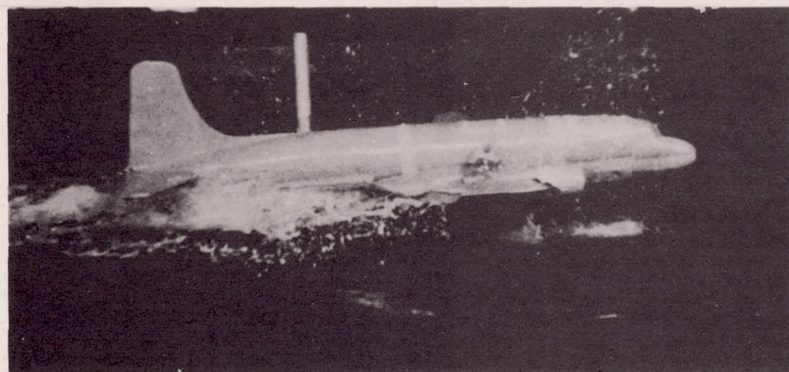
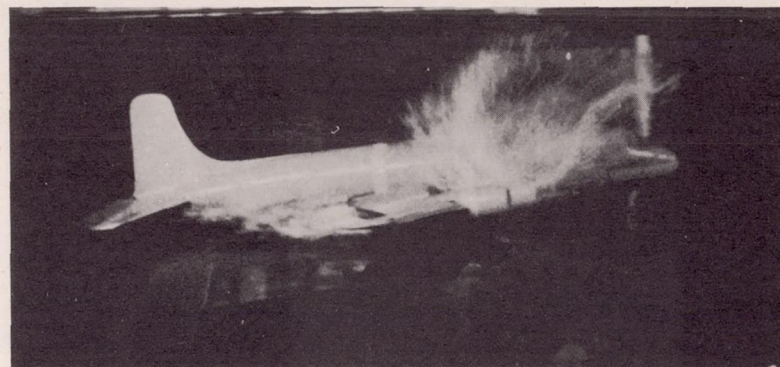
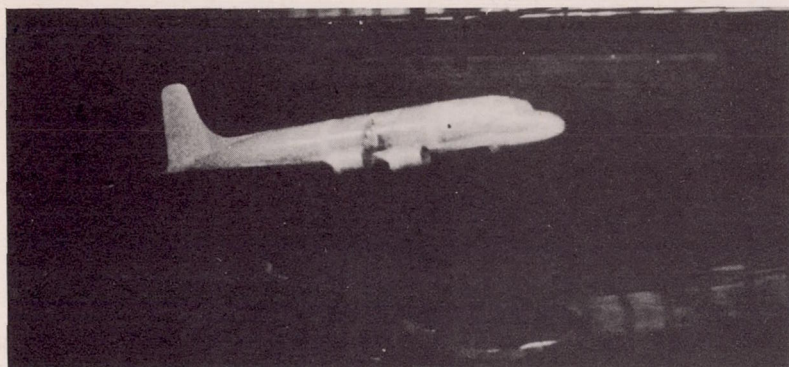
Figure 7.- Sequence photographs of Douglas DC-4 model. Landing attitude, 12° ; landing speed, 91 miles per hour; flap deflection, 50° ; landing-gear doors removed; scale-strength bottom installed. All values are full scale.



(b) $2\frac{1}{2}$ -foot waves. Time interval, 0.50 second.

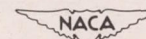
Figure 7.- Continued.

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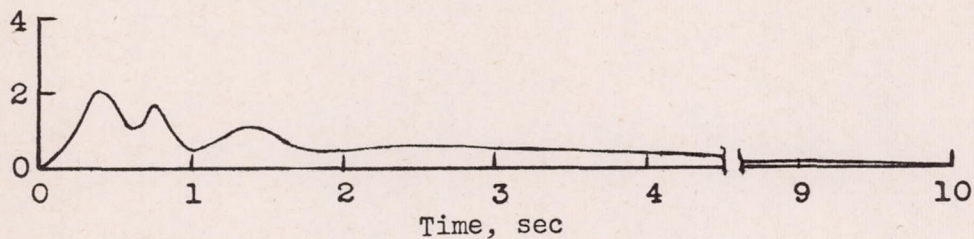


(c) 6-foot waves. Time interval, 0.75 second.

Figure 7.- Concluded.

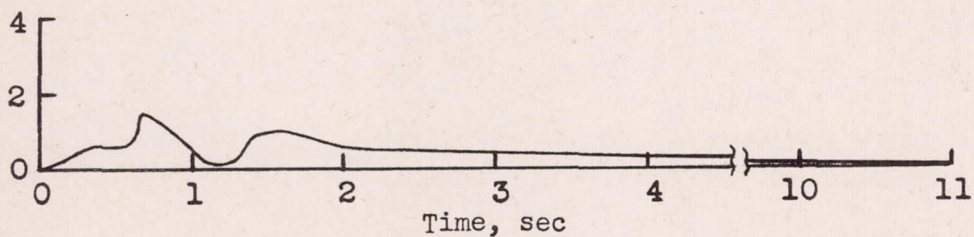


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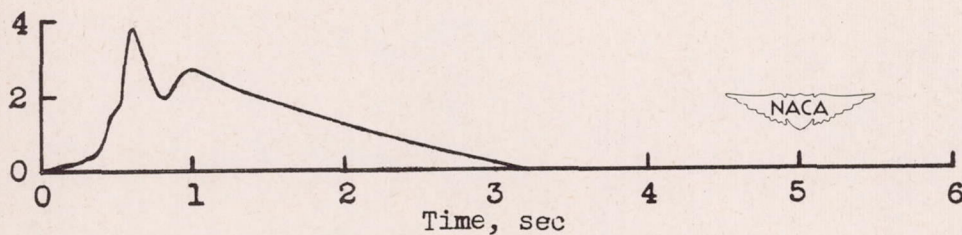


(a) No damage simulated; flap deflection, 0° ; landing speed 126 miles per hour.

Longitudinal deceleration, g

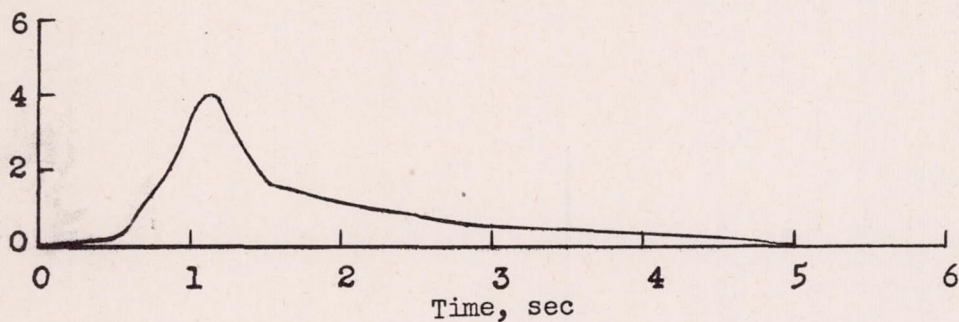


(b) No damage simulated; flap deflection, 50° ; landing speed, 98 miles per hour.

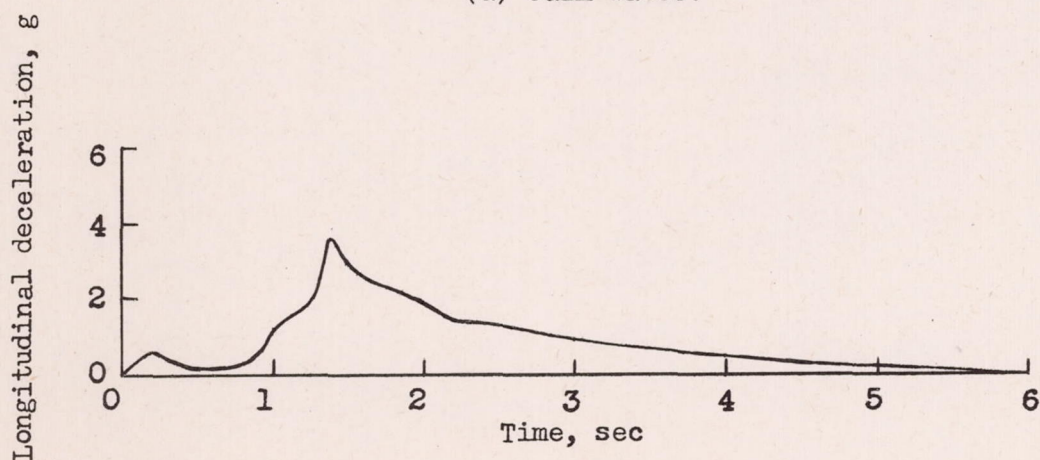


(c) Landing-gear doors removed; scale-strength bottom installed; flap deflection, 50° ; landing speed, 98 miles per hour.

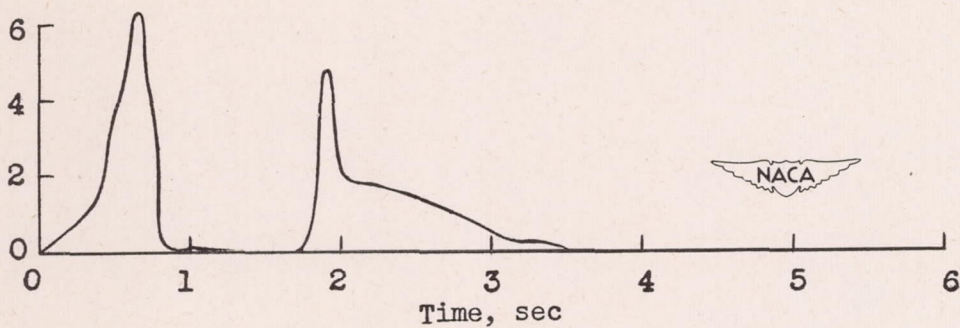
Figure 8.- Longitudinal decelerations of Douglas DC-6 model in calm water. Landing attitude, 12° . All values are full scale.



(a) Calm water.

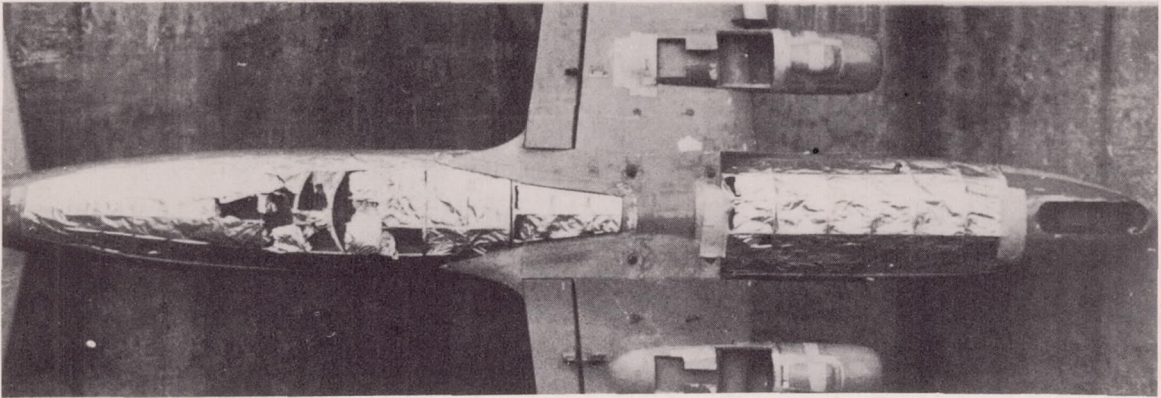


(b) $2\frac{1}{2}$ -foot waves.

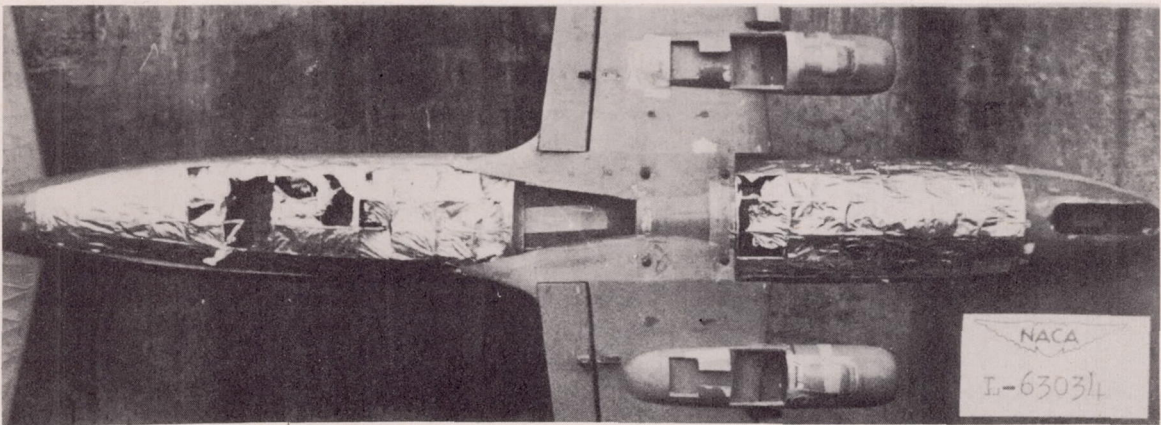


(c) 6-foot waves.

Figure 9.- Longitudinal decelerations of Douglas DC-4 model in calm and rough water. Landing attitude 12° ; landing speed, 91 miles per hour; flap deflection, 50° ; landing-gear doors removed; scale-strength bottom installed. All values are full scale.

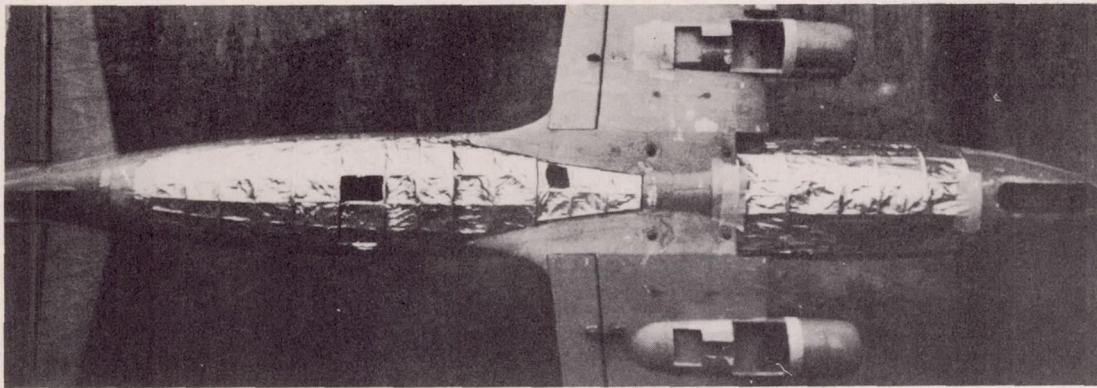


Landing attitude, 12° .

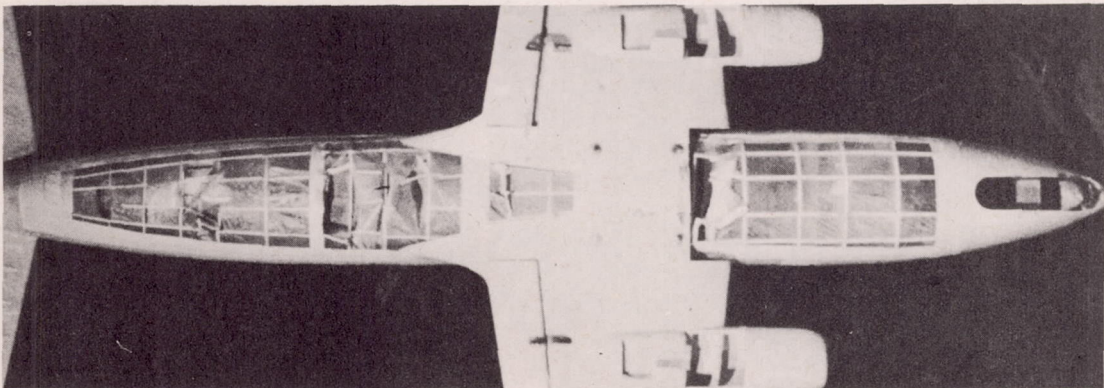


Landing attitude, 7° .

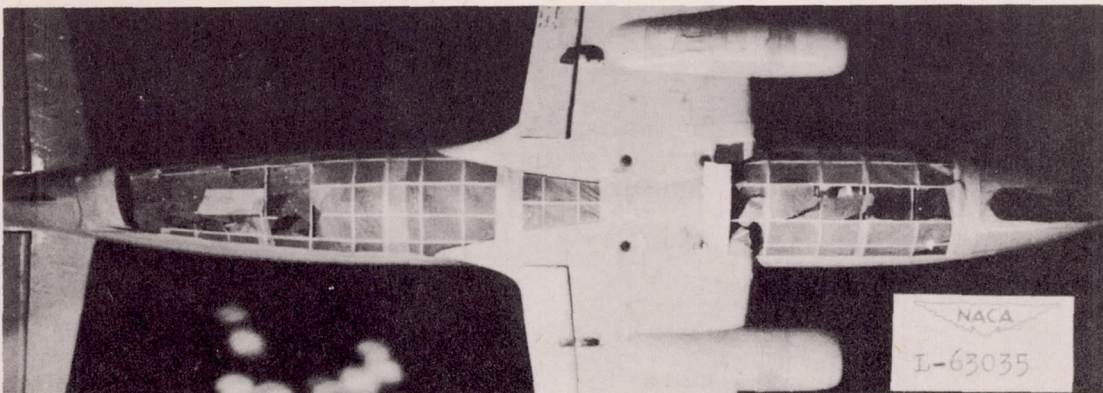
Figure 10.- Damage sustained by scale-strength bottoms on Douglas DC-6 model in calm water. Flap deflection, 50° ; model ran deeply.



Landing attitude, 12° .

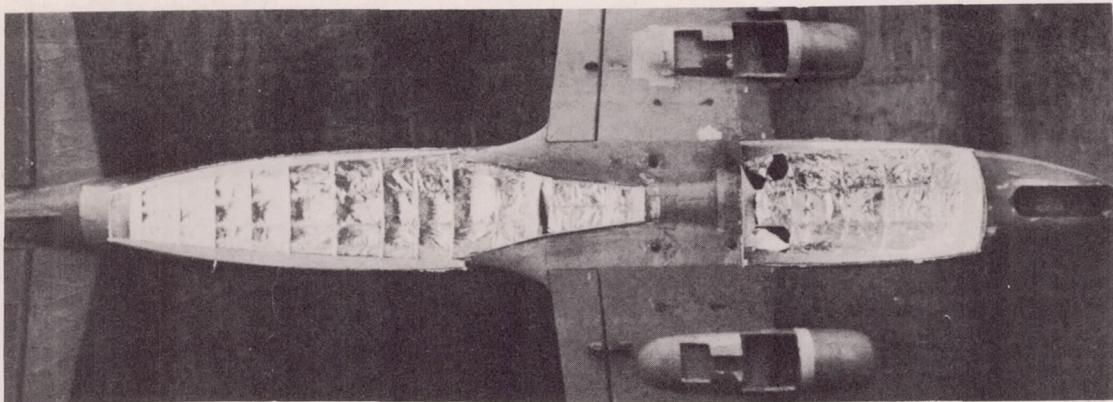


Landing attitude, 12° .



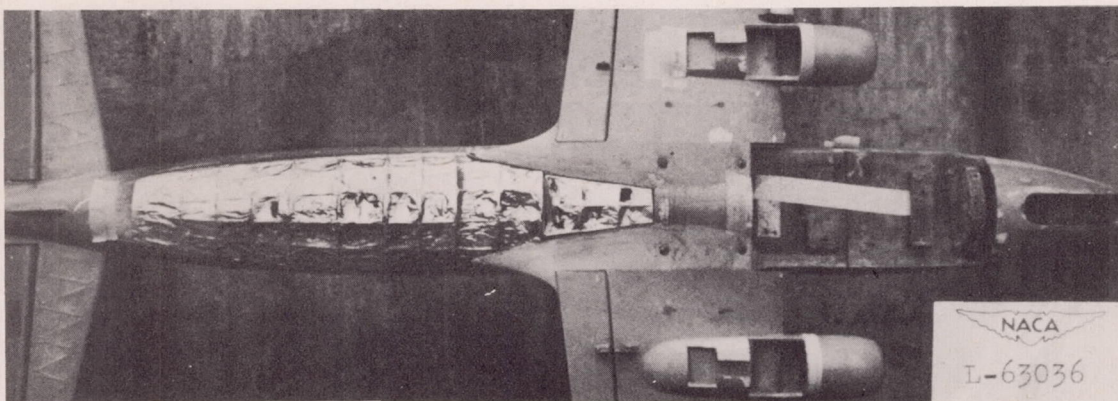
Landing attitude, 7° .

Figure 11.- Damage sustained by scale-strength bottoms on Douglas DC-4 model in calm water. Flap deflection, 50° ; model ran deeply.



$2\frac{1}{2}$ -foot waves

Model ran deeply



6-foot waves

Tail touched wave crest, section under wing hit oncoming wave crest, section forward of wing hit next wave crest

Figure 12.- Damage sustained by scale-strength bottoms on Douglas DC-4 model in rough water. Landing attitude, 12° ; flap deflection, 50° .